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Abridgment

Reanalysis of California Driver-Vision Data: General Findings

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Early studies of the relations between driver vision and accidents were contradictory in their findings, largely because of the small sample sizes used. However, in 1967 and 1968, Burg (1, 2) published the findings of a study in which visual measurements made on over 17 500 California drivers were compared with their 3-year driving records, which included over 5200 accidents. It remains to a considerable extent the most comprehensive study of driver vision yet accomplished.

Taking the driving population as a whole, Burg found very weak but statistically significant correlations between various vision scores and driving records. The vision test that best predicted accidents proved to be a nonstandard one—dynamic visual acuity (DVA), in which the observer had to resolve detail in a rapidly moving acuity target; however, by itself, DVA remained a poor predictor of a driver's accident rate. This and other general findings of Burg's study reflected both the multicausal nature of traffic accidents and the need to develop tests of visual perception that are more relevant to the driving task than the classical tests of vision (which were largely devised for reading purposes).

Vision standards for driver licensing require not only the selection of valid visual characteristics to be tested but also the establishment of valid cutoff scores as criteria for passing or failing. To date there has been virtually no research into the latter problem, and this study was conducted with this need in mind. This paper summarizes the major findings of the study and is taken from a more detailed report (3).

The study explored in depth the implications of Burg's data for driver-vision standards and concentrated on determining whether certain subgroups of the driving population displayed stronger relations between vision and driving than did others. Preliminary work suggested that analysis of older drivers rather than of those with poor vision was most likely to show these stronger relations. Therefore, in the main analyses, the sample was divided into four age groups: under age 25, ages 25 to 39, ages 40 to 54, and over age 54.

VISION TESTS

The vision tests used by Burg included the following:

1. Static visual acuity (SVA)—binocular distance acuity measured by using the Bausch and Lomb Ortho-Rater (F-3 test) and, for a subsample of the total population, a Snellen chart;
2. Dynamic visual acuity (DVA)—the ability to perceive a series of rapidly moving (Ortho-Rater) checkerboard acuity targets projected on a cylindrical screen at two angular rotation speeds: 90°/s and 120°/s;
3. Low-light recognition threshold—the threshold amount of light required to recognize familiar targets;
4. Glare recovery—the length of time taken by the subject to reattain the low-light recognition threshold after exposure to 5-s glare; and

5. Field of vision—total horizontal visual field, both eyes combined.

DRIVING RECORD VARIABLES

Research has clearly shown that the number of kilometers driven (quantitative exposure to risk) is a fundamental factor in predicting the number of accidents and convictions for traffic violations experienced by a driver. In this study, therefore, only accident and conviction rates [per 161 300 km (100 000 miles) driven] were considered as driving record variables, to minimize the influence of exposure. Furthermore, 98 drivers with average annual distances driven of less than 1613 km (1000 miles) were excluded from the analyses since they were found to be highly atypical of the total sample on a number of critical driving and personal characteristics. The total sample ultimately analyzed numbered 14 283.

COMPARISON OF STATIC ACUITY TESTS

The primary test instrument for determining binocular static acuity in the Burg study was the Bausch and Lomb Ortho-Rater, which uses checkerboard visual targets (the same instrument was used for official testing of applicants for drivers' licenses in California where the study was conducted). To permit a comparison of two common test methods, binocular static acuity was also measured for a subsample of 4753 subjects by using a Snellen chart. In view of the fact that current proposals for the harmonization of European standards are based on wall charts that use either the Snellen alphabetic characters or Landolt C-rings, the results of the comparison are of interest.

As might be expected, the results showed that there is an approximately linear relation between the two acuities; however, the product-moment correlation coefficient is only 0.70, hardly enough for accurate prediction of one score from another. Although the two acuities coincide at 20/20, the slope is not 45°; 20/40 Snellen was found to be approximately equivalent to 20/30 Ortho-Rater, whereas 20/40 Ortho-Rater was equivalent to about 20/67 Snellen. While 46 of the sample would have failed a standard of 20/40 Snellen, only 18 would have failed a 20/40 Ortho-Rater standard, a dramatic difference in failure rate. These differences are believed to be attributable to the repeated pattern of the checkerboard, which would appear to be more resistant to spherical or certain cylindrical blurrings than the more complex form of alphabetic letters.

This divergence between Snellen and Ortho-Rater acuities at the poor-vision end of the spectrum is clearly of significance when international comparisons are made of standards for driver vision and must be taken into account in considering the analyses for SVA that follow. It is not known whether this relation would also apply to different measures of dynamic acuity.

DATA ANALYSES

The primary data analyses investigated relations between vision and driving as a function of both age and level of visual performance and used correlational analysis and t-tests to determine the statistical significance of differences in mean accident rates for various subgroups of the sample. The results were quite different for the over 54 age group compared with those for the three younger age groups; therefore, this age group is discussed separately.

Drivers Age 54 and Younger

The data analyses revealed no significant relation between accident rate and any of the visual performance measures studied for the three younger age groups. It is felt that for young drivers factors other than vision, such as experience, are likely to be more highly correlated with accidents whereas for all age groups any deterioration in visual performance might be at least partially compensated for by modifications in driving behavior (such as reduced speed and increased headways), by changes in looking behavior, and perhaps by improved manipulative skills. It may well prove that a higher order visual test—for example, a test of hazard perception—is a more effective accident predictor for these younger age groups than the tests of more basic visual abilities examined in this study (4). Henderson and Burg (5) suggest that tests of perceptual ability rather than sensory capability are more likely to be related to driving performance, which suggests the need for more complex performance tests that involve cognitive as well as sensory aspects.

Drivers Over Age 54

Weak relations were found between certain of the visual tests and accident rates for the oldest age group. DVA and SVA tests showed the most systematic and consistent relations; 90°/s DVA exhibited a slight superiority. Although they were significant, the correlation coefficients found were very low, which indicates that for an individual driver the accident prediction value of these tests is poor. A more detailed age analysis failed to define more precisely the age at which these relations develop although evidence was found to suggest that there are marked differences in the way they develop under daytime and nighttime conditions.

The results for the two tests of night vision—low-light recognition threshold and glare recovery—were regarded as inconclusive for the over 54 age group although glare recovery was the more promising of the tests. The test of total visual field is discussed below.

Total Visual Field

For the over 54 age group, there was no evidence of a progressive increase in accident rate with decreasing total visual field. In addition, no evidence was found to support a vision standard of 140° (as adopted by a number of states and recommended by the World Health Organization, the American Optometric Association, and a number of other bodies). These findings are in general agreement with those obtained by previous researchers.

Developing Cutoff Scores for Driver Licensing

A systematic attempt was made to find out whether vision test cutoff scores that might be considered valid for purposes of driver screening could be determined. This was done by systematically varying the pass score from the highest to the lowest levels of visual performance for each test and then using t-tests to determine for each pass score the statistical significance of the difference in mean accident rate between the pass and fail groups.

The results of these analyses were in keeping with those of the correlational analyses described above. For the three younger age groups, the vision tests provided no cutoff scores that could be considered consistently valid and useful. For the over 54 age group, however, useful cutoff scores were found for both static and dy-

namic acuity. The most consistent results were obtained for 90°/s DVA, where both 20/50 and 20/67 cutoff scores proved highly significant. The 20/67 score failed 6 percent of the age group, and the mean accident rate for this fail group was twice that of the pass group.

An Ortho-Rater static acuity cutoff score of 20/40 placed 1.6 percent of the drivers over age 54 in the fail group, and their accident rate was 2.5 times that of the pass group. But since it was determined that this result was applicable solely to male drivers, its usefulness for female drivers is questionable.

For total visual field, a cutoff score of 170° was highly significant; however, such a standard would fail nearly 80 percent of the over 54 age group, an obviously impractical ratio of selection. The results for low-light recognition threshold and glare recovery were not consistent.

DISCUSSION OF RESULTS

If a vision test is to be successful in screening applicants for drivers' licenses, it must correctly identify a maximum number of drivers in the target group, i.e., those with both bad vision and unacceptable accident rates, while at the same time minimizing the number of drivers identified as having bad vision but acceptable accident rates. Table 1 illustrates this point by giving the number and percentage of drivers over age 54 who fall into each of several categories based on combinations of vision score and accident rate. Four values are chosen as examples of acceptable accident rate: the sample mean and two, three, and four times the sample mean. A score of 20/40 Ortho-Rater static acuity is used as the vision test cutoff (passing) score because it was found to be highly significant and gave the largest difference in mean accident rate (2.5:1) between the fail and pass groups of all the static acuity levels tested. (However, it is possible that more significant results might have been obtained at a level of acuity intermediate to those available in the Ortho-Rater.)

Data given in Table 1 show that using an accident rate of 3.88 to define the maximum acceptable and then the 20/40 cutoff identifies only 8 of the 250 drivers with unacceptable accident rates and would reject 40 drivers with acceptable rates. A simple index of merit is shown that suggests that this is the best performance of the test for the four definitions of acceptable accident rate considered. However, such a simple index is not likely to be an adequate one in view of the social costs of denying a license to 40 acceptable drivers in order to remove 8 unacceptable drivers from the road. A more valid index must take into account all of the social and political costs and benefits associated with each category.

As indicated earlier, accident rate rather than accident frequency was used as the accident-record criterion because the former takes into account exposure to risk (distance driven) as a factor causing accidents. The analyses supported this decision by demonstrating that, if accident frequency is used as the criterion instead of accident rate, then the 20/40 Ortho-Rater cutoff score is even less successful in identifying drivers with unacceptable accident experience. For example, at the expense of denying a license to 47 acceptable drivers, this cutoff score identifies only 1 of the 86 drivers over age 54 who had more than one accident in 3 years.

It should be pointed out that older drivers drive much less than do younger drivers (1), and the use of accident rates as a basis for vision standards can therefore lead to the paradoxical situation in which older drivers who failed a test would have fewer accidents per year than younger drivers who passed it. This raises a number of social and political issues that are outside the scope of this study.

SUMMARY

In summary, it must be said that, as a basis for vision standards that are valid in terms of potential accidents saved, the tests studied must be regarded as disappointing. The failure to find a direct relation between poor visual performance and high accident rate for young and middle-aged drivers has been consistent throughout the study, and, for the over 54 age group, the relations obtained are significant but weak. The ability of these tests to identify drivers likely to have accidents—without paying an unacceptably high penalty in the rejection of good drivers—remains questionable.

These findings lend support to current attempts to find perceptual tests of visual performance that are much better accident predictors than the largely classical sensory tests of vision studied here. (Tests of contrast sensitivity, movement perception, and hazard perception are among those currently being examined, and it is recommended that investigation of other stimulus conditions for the promising glare-recovery test be carried out.)

It should be stressed that the significant relations found for older drivers may not be causal. A driver's visual performance in this age range may merely reflect his or her "effective" (or phenomenal) age, and some other factor such as deterioration of the brain's central processing capacity may be the fundamental cause of increased accident rates. Thus, improving a driver's visual performance may not improve his or her accident rate; however, even if a measure of visual performance is not causally related to accident rate, any predictive power it may have could still be valuable for the purposes of screening or visual standards.

Table 1. Effectiveness of Ortho-Rater binocular SVA cutoff score in differentiating drivers over age 54 with acceptable and unacceptable accident rates.

Acceptable Accident Rate (accidents/161 300 km)	Over 54 Age Group								Simple Merit Index[b]
	Pass Score (20/40 or better)				Fail Score (worse than 20/40)				
	a (drivers with acceptable accident rate)		b (drivers with unacceptable accident rate)		c (drivers with acceptable accident rate)		d (drivers with unacceptable accident rate)[a]		
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	
≤0.97 (sample mean)	2436	81.9	491	16.5	38	1.28	10	0.34	1.31
≤1.94	2501	84.1	426	14.3	38	1.28	10	0.34	1.55
≤2.91	2607	87.6	320	10.8	40	1.34	8	0.27	1.63
≤3.88	2685	90.3	242	8.13	40	1.34	8	0.27	2.22

Note: 1 km = 0.62 mile.

[a]Target group. [b][(d/c)/(b/a)].

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Abridgment

Roadside Hazard Model

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One category of traffic accidents that has received increased attention in recent years is the collision of a single vehicle with an object adjacent to the roadway. These single-vehicle, fixed-object (SVFO) accidents constitute approximately 17 percent of all reported accidents, and the probability of occupant injury in these accidents is significantly higher than is the probability for the complementary set of accidents. In an effort to develop cost-effective solutions to this problem, the Maryland Department of Transportation sponsored a study of these collisions on state-administered roads other than freeways. The objective of the study was to identify and quantify the parameters associated with SVFO accident severity and probability and to incorporate them into a hazard model. Previous reports (4, 5) have described the preliminary findings, and this abridgment presents the results of the concluding phase of the study.

INPUTS TO A ROADSIDE HAZARD MODEL

Field surveys conducted as part of the first phase of this study identified numerous objects adjacent to the roadway. A majority of these objects, including drainage facilities, traffic signal supports, and utility poles, were manmade. The number of these elements, coupled with the cost and logistical problems of their removal, relocation, or redesign, requires that attention be devoted to those elements that (a) result in injury to the occupants of striking vehicles and (b) are relatively more likely to be struck.

Severity

The degree to which a particular type of object results in injury to vehicle occupants can be quantified by its severity index (SI). From 1970 to 1975, reported SVFO accidents on Maryland and U.S. routes had an average SI of 0.44. The severity indexes determined from accident records are average values for all reported SVFO accidents. Caution must be exercised in using these averages primarily because of a significant number of unreported accidents.

All other factors being equal, accidents at higher speed will result in a larger frequency of injuries. Rural highways have more severe accidents although some SVFO accidents on 47- to 56-km/h suburban arterials, especially those that occur at night when traffic volumes are relatively low and involve drivers who are in "other than normal" condition, occur at high speeds. Accident records indicate that 44 percent of SVFO accidents involve drivers who are traveling at speeds too fast for conditions. A general model for determining the priority of roadside-hazard improvements must incorporate some speed-related parameter to highlight locations where SVFO accidents are likely to be more severe.

The most serious problem that is not reflected in accident records or accounted for by the SI is the variation in object design. For example, a variety of guardrail designs are used; W-beam designs are the most common, but single- and multiple-wire cable guardrails are also used. Various mounting heights are used in conjunction with blunt, flared, or buried terminals. Similar variations exist for the designs of other fixed objects and are of considerable importance because they affect the severity of SVFO accidents.

Probability of Impact

It is also essential for the hazard model to incorporate the likelihood of impact with a fixed object. Based on this research, the most important factors are traffic exposure, roadway geometrics, and placement of fixed objects.

The extent to which traffic is exposed to the object is partially reflected by the traffic volume on the route. However, volume by itself is not directly related to SVFO accident experience since multiple-vehicle accident experience increases at higher volumes whereas single-vehicle accidents decrease. Traffic volume is also related to roadway characteristics—notably road width and shoulders—that are associated with the frequency of roadside encroachments (3, 7). This research found